Constellation-X Cooling System

Constellation-X Technology and Project Status Meeting

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Constellation-X Cooling System

Requirements

- Mechanical cooler to heat sink sub-Kelvin cooler and for thermal shields

- Sub-Kelvin cooler to operate sub-Kelvin microcalorimeter array

Alternatives technologies

- Mechanical coolers for sub-10 Kelvin:
  - Turbo-Brayton cooler
  - Hybrid Stirling/J-T cooler
  - Multi-stage pulse tube cooler
  - Sorption cooler
  - Multi-stage Stirling or pulse tube cooler with heat sink at 12 Kelvin
    - Requires a multi-stage ADR with 12 Kelvin heat sink

- Sub-Kelvin coolers:
  - ADR
  - Dilution refrigerator

Turbo-Brayton Cooler
Sub-10 Kelvin Mechanical Coolers

Recent Progress

- 70 Kelvin turbo-Brayton cooler flown on HOST shuttle mission
  - Performed flawlessly
  - Turbo-Brayton cooler will be flown on HST 3rd Servicing Mission

- Performed test on turboalternator with helium gas at 12 Kelvin
  - Provided information required to design 4 – 10 K turboalternator

- In 2000, Creare will design, fabricate and test a prototype 6 – 8 Kelvin turboalternator designed to NGST requirements
  - Design of turboalternator nearing completion
  - Piece part fabrication techniques being explored

Turbo-Brayton Cooler
Sub-10 Kelvin Mechanical Coolers

Plans for 2000

- In 2000, Creare, Inc. will design, fabricate and test a prototype 6 – 8 Kelvin turboalternator designed to NGST requirements
  - Funded by Cross Enterprise Technology

- Creare will submit proposal to Cross Enterprise Technology to develop a 6 Kelvin turbo-Brayton cooler
  - Cooler would be designed to meet NGST requirements
  - To obtain Cross Enterprise funding will require support from NGST and Con-X

Multi-Stage Stirling/J-T cooler
Sub-10 Kelvin Mechanical Coolers

Recent Progress

- Ball Aerospace is attempting to develop a multi-stage Stirling/J-T cooler based on their existing 35/60 Kelvin 3-stage Stirling cooler

- A contract has been issued to demonstrate a 3-stage Stirling pre-cooler for the J-T-stage
  - Will pre-cool JT to 15 Kelvin Kelvin
  - Should be capable of providing a heat sink for a 12 Kelvin ADR

- Redstone (centrifugal) compressor for the J-T-stage is under development
  - Lifetime studies on the carbon vane wear rate are encouraging

Multi-Stage Stirling/J-T cooler
Sub-10 Kelvin Mechanical Coolers

Plans for 2000

- Ball has Air Force funding for FY00
  - Complete assembly of compressor 4/00
  - Complete performance test 5/00
  - Begin extended life test 5/00
  - Complete extended life test 1/01

- A Phase I SBIR has been issued to Jim Lester to support the Redstone compressor for the J-T-stage

Multi-stage Pulse Tube Cooler
Sub-10 Kelvin Mechanical Coolers

Recent Progress

- Lockheed demonstrated a low temperature pulse tube-stage operating at nominally 7 Kelvin (with 15 Kelvin heat sink)
  - Demonstrates the feasibility of a small multi-stage pulse tube cooler operating at 6 to 8 Kelvin

Plans for 2000

- No funding to produce a sub-10 Kelvin pulse tube cooler

Sorption Cooler
Sub-10 Kelvin Mechanical Coolers

Recent Progress

- JPL has completed a conceptual analysis of a multi-stage sorption cooler for NGST
  - Hydrogen chemical adsorption upper-stage with 35 Kelvin radiator
    - Requires large radiator – over 10 square meters at 35 Kelvin
  - Helium adsorption lower stage
    - Carbon getter must function with unusually high temperature heat sink (18 Kelvin)

Plans for 2000

- No funding to produce a sub-10 Kelvin sorption cooler

12 Kelvin Multi-stage Stirling Cooler + 12 Kelvin ADR
Sub-10 Kelvin Mechanical Coolers

Plans for 2000

- Ball intends demonstrate their 3-stage Stirling cycle cooler at 12 Kelvin

- An ADR with a 12 Kelvin heat sink requires a low field, Nb_3Sn magnet
  - Also requires either an additional demagnetization stage or better paramagnetic materials

- No funding to produce a 12 Kelvin continuous ADR

Adiabatic Demagnetization Refrigerator
Sub-Kelvin Coolers

Recent Progress

- Continuously operating ADR demonstrated
  - Good temperature control maintained throughout cycle
  - Continuous cycle produces more uniform heat load on the cryocooler, reduces mass, and allows automated, transparent ADR operation

- New paramagnetic materials being investigated:
  - DGG/GGG combinations, paramagnetic materials with nanocomposites, among others
  - New materials should allow the use of a cryocooler with a 6

- Two-stage, ground-based ADRs are becoming common
  - Several universities and national labs have produced ADRs

Adiabatic Demagnetization Refrigerator
Sub-Kelvin Coolers

Plans for 2000

- Received director's discretionary funding in FY00 to develop a liquid gap heat switch
- Submitting proposal to Cross Enterprise Technology to develop technology for a continuous operating ADR
  - Would develop components for ADR with 6 Kelvin heat sink, including heat switches and advanced paramagnetic materials

Dilution Refrigerators
Sub-Kelvin Coolers

Recent Progress

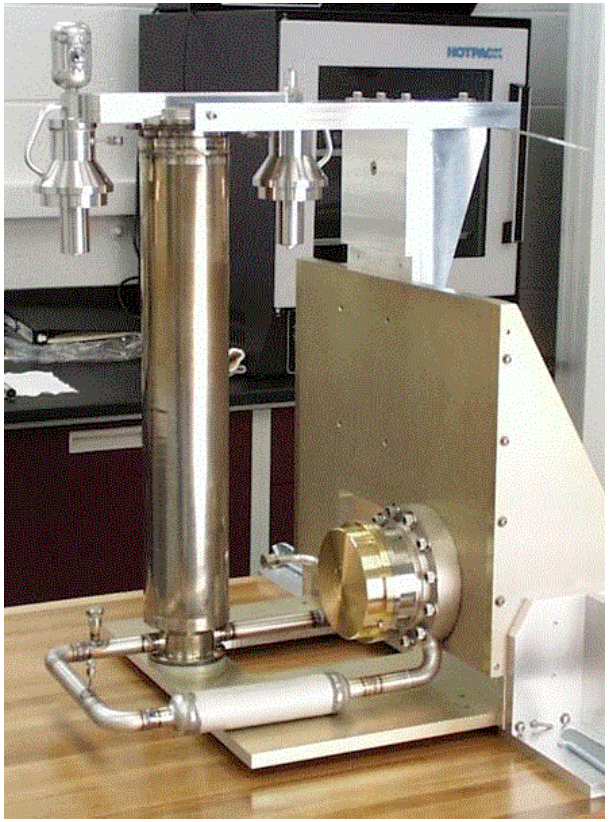
- Ames Research Center attempting to improve the thermodynamic efficiency of dilution refrigerators

Plans for 2000

- Ames Research Center has funding from microgravity for at least FY00 and FY01
  - In FY00 will develop heat switches to enable continuous operation of dilution refrigerator

Turbo-Brayton Cooler

NICMOS Cooler



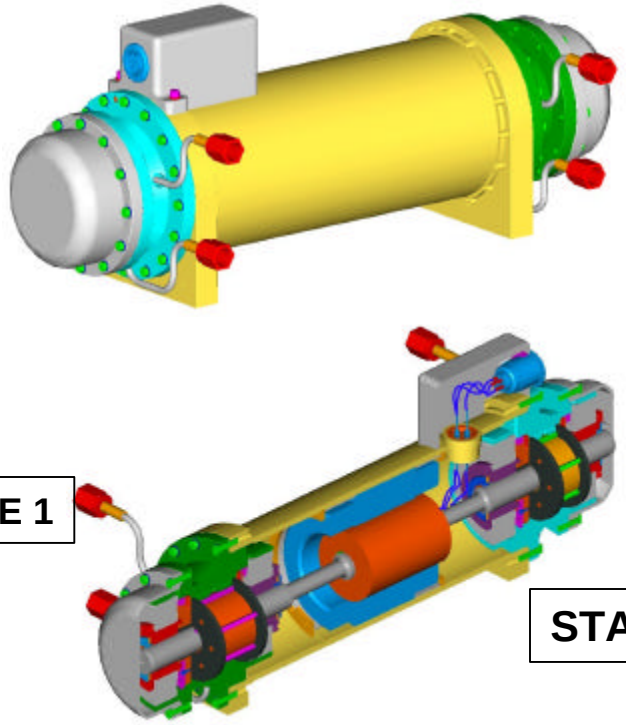
Turboalternator shaft

Redstone Compressor

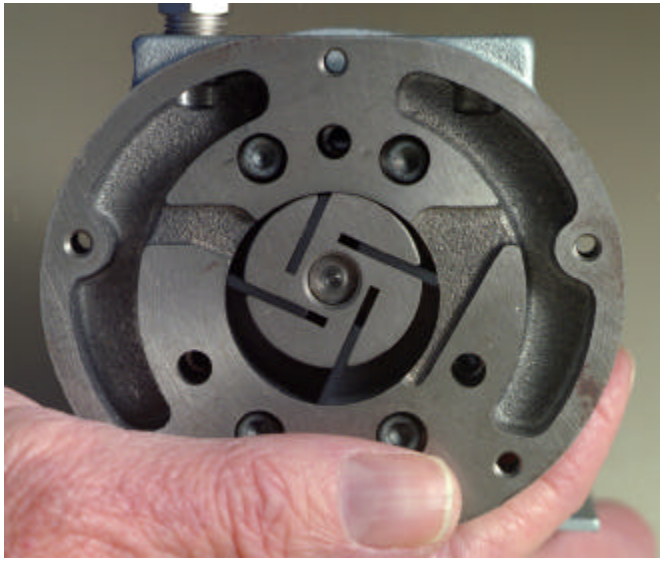
2 Stage Rotary Vane Compressor:

Length: 11.98” x Height: 4.70” x Width: 3.38”

Weight: ~10.5 lbs



Picture of carbon vanes

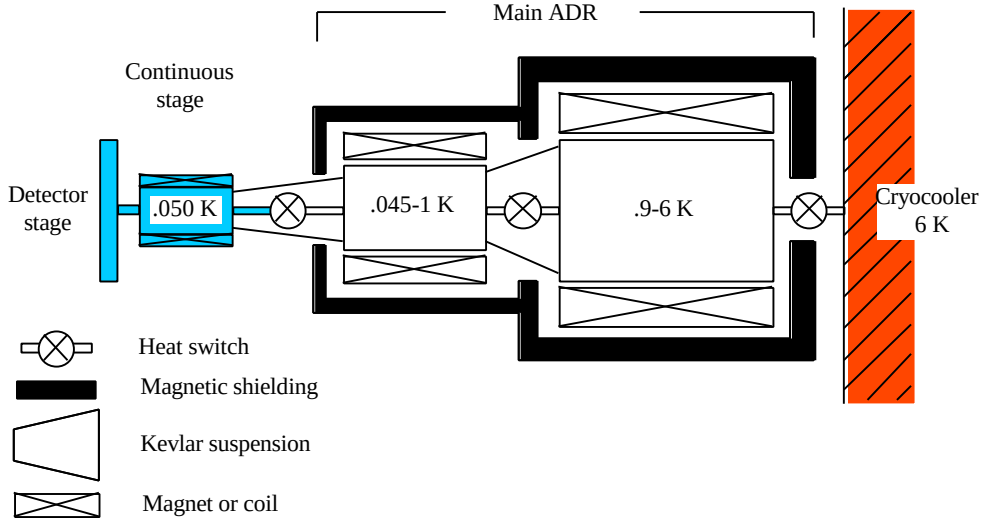


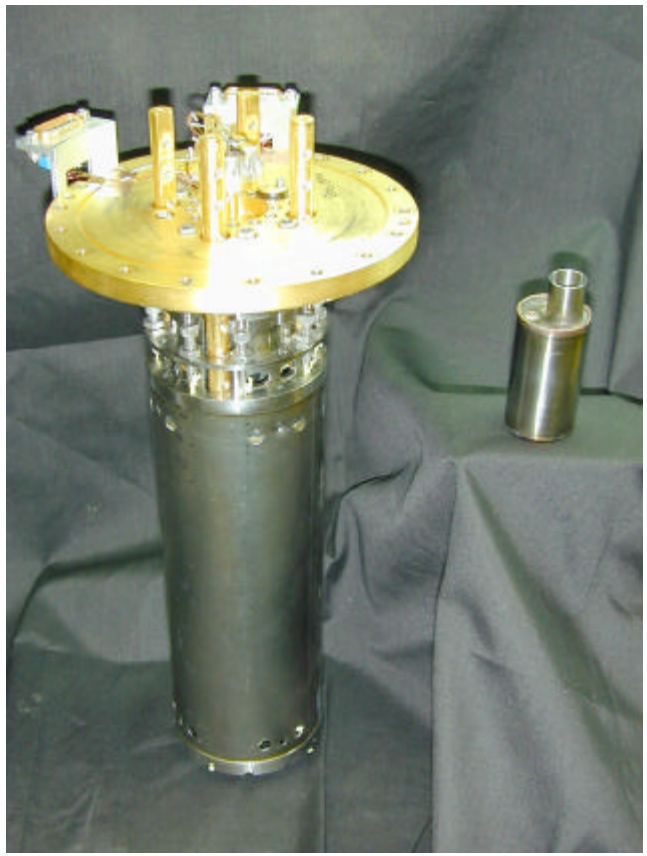
Ball Multi-stage Stirling Cooler

- Single-stage to fly on EOS-Chem
- Two-stage on 2nd year of life test
- Three-stage tested for dual detector cooling at 35K and 60 K
- Three-stage cold finger being re-configured for 15 K cooling

Ball 30 K Cooler
in GSFC 6-axis dynamometer

Continuous ADR





- Continuous operation
  - Allows system to operate on a short time scale
  - Reduces mass and size
  - Increases cooling power per unit mass
  - Allows use of a cryocooler heat sink
    - ➢ Smoothes out heat load on the cryocooler
    - ➢ Maximizes cryocooler efficiency
  - Can achieve 10 µW at 50 mK for less than 15 kg

Left: XRS ADR (0.3µW at 60mK)

Right: Continuous ADR stage (10µW at 50mK)

FY99 DDF Results

- Successfully demonstrated
  - Continuous cooling at 100 mK
  - Techniques for fabricating small, high cooling power “salt pills”